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Technology Opportunity

Technology Transfer & Partnership Office

TOP3-00152

Web Growth of Silicon Carbide Surfaces

Technology

This Technology Opportunity sheet describes processes to control the location of, or eliminate dislocation defects (including micropipes) in silicon carbide (SiC) single-crystal semiconductor materials. These technologies expand the capabilities of the technology described in TOP3-00149.

Benefits

The performance of electronic devices is often affected by the quality of the material used to make those devices. Poor quality material and surfaces that contain too many defects (including dislocations) have been shown to negatively impact the performance of SiC semiconductor devices. By controlling the location of dislocation defects, or eliminating them altogether, these new technologies provide defect-free material on which devices can be built, which leads to

- Improved performance of devices
- Extended life of devices
- Higher yields of devices

Commercial Applications

- Surface-sensitive SiC devices
 - Metal/oxide semiconductor field effect transistors (MOSFETs)
 - Schottky diodes
- Wide band gap III nitride devices built on SiC substrates
 - Blue lasers
 - Blue LEDs (light-emitting diodes)

- High-power and high-frequency devices for radiofrequency amplifiers
- Nanoscale devices and microelectromechanical systems (MEMS)

Technology Description

The first step in web growth of SiC is to etch arrays of mesas into commercially available SiC material. However, the mesas for web growth have branched geometries, which are different than the solid, square mesas described in TOP3-00149. As material is deposited on top of the branched mesa, under controlled step-flow conditions, thin lateral cantilevers extending from branches of the mesa begin to grow together, forming a webbed surface of SiC, free of dislocation defects. As additional material is deposited, the web extends to cover the entire area between the branches.

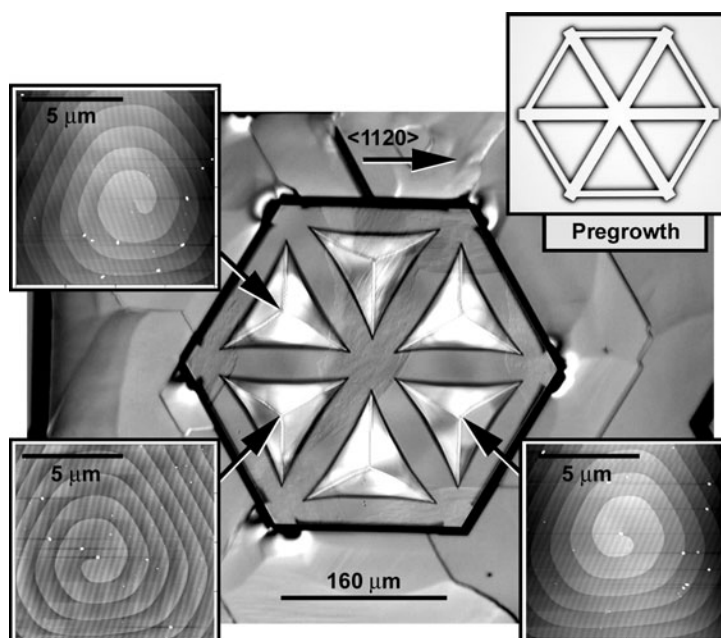


Figure 1.—Enclosed "hexagon" mesa, showing dislocations located at points of final coalescence.

NASA Glenn's researchers have documented that "enclosed" mesas like the one shown in figure 1 behave differently than "open" mesas like the one shown in figures 2a and 2b.

"Enclosed" mesa geometries relocate and combine dislocation defects to the point of final cantilever coalescence—Based on the principle of Burgers vector conservation, all of the dislocations contained in the enclosed region of the substrate combine into a single dislocation defect in the webbed roof, at the point of final roof coalescence. The rest of the webbed roof is defect free, and so devices can be fabricated to avoid the known dislocation site. As an additional benefit of this technique, the dislocation contained in the web roof provides new growth steps, which are necessary for continued epitaxial growth. This technique has the effect of reducing the number of dislocations in a substrate, by combining multiple dislocations into one.

"Open" mesa geometries lead to atomically flat surfaces—In mesas of this type, defects that are

contained in the substrate area between the branches will overgrow the dislocation, resulting in an atomically flat web surface; devices can be deposited anywhere on this defect-free surface. If a defect is contained in a branch of the original mesa, then the mesa cannot be made flat. This technique reduces the number of dislocation in a substrate by terminating those that fall between branches. However, when a mesa is made atomically flat, the homoepitaxial film cannot grow thicker because dislocations (now absent from the film) are required to grow a thicker film of the same polytype.

Options for Commercialization

Initial industry contacts have expressed interest in working with this technology, and NASA Glenn is pursuing license agreements for its portfolio of wide band gap material patents and patent-pending technologies.

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References

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LEW-17116-1 and 17237

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Key Words

Wide band gap Silicon carbide Blue laser
Gallium nitride High-power electronics

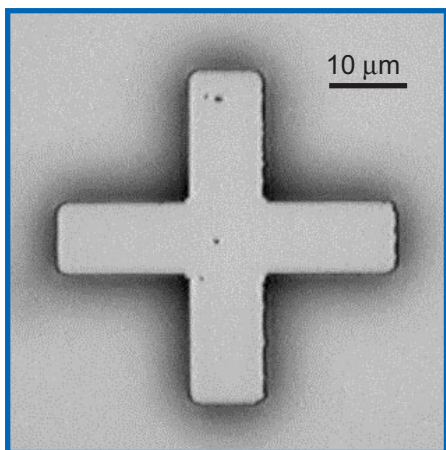


Figure 2a.—"Open" cross mesa shape prior to epitaxial growth.

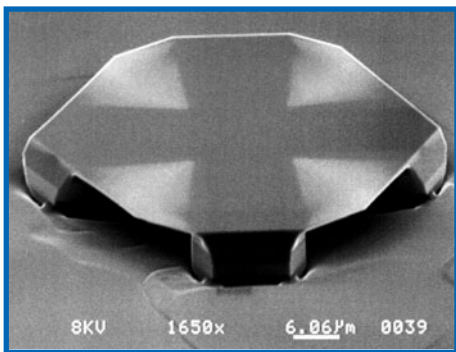


Figure 2b.—SEM of mesa following epitaxial growth.